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ASSESSMENT OF ICT IMPLEMENTATION IN AGRICULTURE

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Abstract. The article looks into the role IT plays in modern agriculture, focusing specifically on its abilities to enhance efficiency, productivity and sustainability. It seeks to answer the question: How does technology empower farmers and what influences their uptake of these innovations? The assessment analyzes various IT uses in agriculture that include precision farming, sensor networks, agricultural robotics, data analytics and mobile applications. The research emphasizes the usefulness of these technologies for efficient resource allocation; waste reduction; increase crop production; better disease management and facilitated market access. Additionally, it explores some factors that may hinder or facilitate ICT adoption in agriculture such as access to technology, digital literacy levels, affordability of terms among others mentioned here. Finally, key strategies are identified that promote broad based technology adoption stressing the importance of collaboration among farmers, policy makers as well as technology developers and research institutions. This all-inclusive analysis is aimed at providing valuable insights to stakeholders engaged with agricultural development by drawing attention to how information technology has the potential for transformative change in agriculture leading to improved farm incomes and fostering sustainable agricultural practices.

Keywords: agriculture, information and communication technology (ICT), market, Internet of Things (IOT), robotics, remote sensing, improved efficiency

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ОЦЕНКА ИСПОЛЬЗОВАНИЯ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ В СЕЛЬСКОМ ХОЗЯЙСТВЕ

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Аннотация. В статье рассматривается роль информационных технологий в современном сельском хозяйстве. Особое внимание уделяется их способности повышать эффективность, производительность и устойчивость. Целью данного исследования является ответ на вопрос: как технологии расширяют возможности фермеров, и что влияет на внедрение этих инноваций? В статье анализируются различные варианты использования ИТ в сельском хозяйстве, включая точное земледелие, сенсорные сети, сельскохозяйственную робототехнику, анализ данных и мобильные приложения. В исследовании подчеркивается полезность этих технологий для эффективного распределения ресурсов; уменьшения отходов; увеличения урожайности сельскохозяйственных культур; улучшения борьбы с болезнями и облегчения доступа к рынку. Кроме того, в нем исследуются некоторые факторы, которые могут препятствовать или способствовать внедрению ИКТ в сельском хозяйстве, такие как доступ к технологиям, уровень цифровой грамотности, доступность и др. Наконец, в результате проведенного исследования были определены ключевые стратегии, которые способствуют широкому внедрению технологий, подчеркивая важность сотрудничества между фермерами, политиками, а также разработчиками технологий и исследовательскими институтами. Комплексный анализ направлен на предоставление ценной информации заинтересованным сторонам, участвующим в развитии сельского хозяйства, путем привлечения внимания к тому, как информационные технологии могут привести к трансформационным изменениям в сельском хозяйстве, ведущим к увеличению доходов фермеров и развитию устойчивых методов ведения сельского хозяйства.

Ключевые слова: сельское хозяйство, информационные и коммуникационные технологии (ИКТ), рынок, Интернет вещей (IOT), робототехника, дистанционное зондирование, повышенная эффективность

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Introduction

There are multitudinous delicate problems in ultramodern farming. Our earth's evolving requirements, as well as those of regulators, customers, food processors, and merchandisers, must be met by growers. Climate change, field mapping, biodiversity loss, which lowers productivity, as well as customers' shifting food preferences and worries about how it is produced, are all sources of growing pressure. Therefore, it is possible to argue that agriculture is a grueling, changeable assiduity. Agriculturists also struggle to keep up with changing profitable conditions, meet the need for more food of exceptional quality while safeguarding the environment, and embracing and understanding new technology. Lack of digitization and crucial communication infrastructure is one of these issues. Technology, on the other hand, is furnishing solutions to

some of these problems in agriculture, indeed though ultramodern agriculture is defying enormous problems. One can therefore concur with robotics engineer George Kantor of Carnegie Mellon University in Pittsburgh, Pennsylvania, who claims that "there is a potential for intelligent robots to change the economic model of farming so that it becomes feasible to be a small producer again"

For instance, if a farmer wanted to map a large field to determine biodiversity, he would need to scout the entire area, which would take time. Nevertheless, with the arrival of technology, similar as satellite imagery and aerial drones, one can map the entire field quickly and identify which fields are under stress. Consequently, it can be said that technology is resolving the issue of low yields by furnishing farmers with strong genetics and field mapping analysis. As a result, if a farmer places the genetics on bettered soil conditions, the yield will be better. Thus, it may be said that technology in agriculture has enabled farmers to increase agricultural yields while lowering labor expenses. By enabling farmers to work smarter, not harder, green house automation technology can help farmers become more productive. Hence, workers might spend lower time on some tasks and further time on other parts of the farm that necessitate surplus attention. Despite the fact that contemporary agriculture offers a wide range of alternatives the results aren't always the same because every farm is different due to its own geomorphology, soils, technologies, and prospective yields.

The primary objective of this study is to assess the major issues that farmers deal with and how technology is delivering solutions in the field of agriculture.

This study aims to identify the features of Information Technology in Agriculture and provide an analysis of their effectiveness in research development, implementation, food and crop production due to the importance of ICT role in various aspects of agriculture and its application in increasing performance of farmers' activity and satisfying consumers' expectations.

Materials and Methods

The research adopts a mixed-methods approach, blending qualitative and quantitative data to comprehensively analyze the effects of ICT implementation in agriculture. Central to the study is an extensive literature review, encompassing academic papers, government reports, and industry analyses, to understand the current dynamics of agricultural sector. Quantitative data collection focuses on key results related to the implementation of ICT in agriculture.

A descriptive analysis method is employed to present a clear picture of current agricultural landscape, highlighting its reliance on information and communication technologies.

The study also incorporates case studies of successful ICT projects providing practical examples of theoretical strategies in action.

Results and Discussion

What does agriculture information technology entail?

“The Harvard Business Review coined the term information technology to make a distinction between purpose-built machines designed to perform a limited scope of functions, and general-purpose computing machines that could be programmed for various tasks” (What is IT/OT convergence, 2024) however, Information and communication technology in agriculture (ICT in agriculture), commonly referred to as e-agriculture, focuses on improving agricultural and rural development through enhanced information and communication processes. E-agricultural is more particularly the conceptualization, design, development, testing, and implementation of novel information and communication technologies (ICTs) in the rural domain, with a strong focus on agriculture. Information technology, as shown in Figure 1 below, covers every layer of every system in a company, from the physical hardware to the operating systems, applications,

databases, storage, servers, and more.

Fig. 1. Shows what IT encompasses

Technology in Agriculture and Its Importance

The way modern farms and agricultural enterprises operate differs greatly from how they did a few decades ago, largely due to technological developments in the form of sensors, machinery, devices, and information technology. Robots, temperature and moisture sensors, aerial photographs, and GPS technology are all frequently used in modern agriculture. Businesses can become more successful, productive, safe, and environmentally friendly thanks to these cutting-edge equipment, robotic systems, and precision agriculture techniques. Thus, the widespread adoption of information and communication technology is essential for the advancement of agriculture in the twenty-first century.

Examples of several technologies are provided below.

The aerial drones and the Netherlands

The latest disruption is the introduction of agricultural drones, and technology advancements have nearly entirely changed agricultural operations. Drones are utilized for plant health evaluations, field analysis, crop monitoring, and agricultural spraying. Based on the real-time data that the drone technology provides, the farming sector has rapidly grown and changed. Thermal sensor-equipped drones locate the areas where irrigation has to be adjusted. For example, sensors calculate the vegetation index after the crops have started to grow and display their health. Agriculture has become more automated and industrialized since the industrial revolution. Artificial intelligence increases automation even more. The use of Artificial intelligence has implications for what is now known as "precision agriculture." Increasing yields while utilizing less water, fertilizer and herbicides is the aim. The Netherlands is well recognized for using unmanned aircraft for a range of uses, including aerial agricultural inspection. Important data about the condition of the soil and the condition of crops can be gleaned from aerial images. Trimble is an agricultural drone manufacturer, an American company that provides services to numerous transnational sectors including farming, construction and transportation. In 1978, Charles Trimble established the business. Robert Painter leads the company as CEO (Agricultural solutions, 2024; Zagazezheva, Berbekova, 2021).

Yamaha Industrial Unmanned Helicopters are a compact, economically viable helicopter UAV that can be utilized to satisfy Japan's needs for agricultural dusting and spraying. The "R-50" from Yamaha Aero Robot is an artificial helicopter that can carry 20 kg of goods effectively.

Recent years have seen problems plaguing the Japanese agriculture sector, including the aging of the labor force and a lack of younger generation successors. The interest in the Yamaha artificial-use unmanned helicopters is due to the fact that they are cutting-edge agricultural instruments that are both economical and environmentally benign. They are now heavily used for crop dusting (Sato, 2003).

Fig. 2. Process of a drone spraying

The use of drones has grown significantly in the Netherlands in the past few years. Every farm owner in the nation of Holland who raises fresh produce may use a drone to spray his crops in the future. A drone being utilized for spraying is shown in Figure 2.

Driverless agricultural machines in Germany and Israel

A high-tech business has quickly emerged from agriculture. Robotic technology enables efficient crop management and monitoring. Because of its use, the crop is produced more safely and effectively. Precision farming, as the name implies, also helps to lower food prices and minimizes the negative impacts on the environment by carefully applying fertilizer or pesticides to the correct plant. Additionally, farming robotic arms are enhancing farmers' crop production in a variety of ways. One of the most popular robotic uses within agriculture consists of harvesting and collecting because of the degree of precision and quickness that robots can achieve. As a result, there will be a higher yield along with decreased crop residue from crops that are left in the field after harvesting (Stoces, 2016). However, automating some applications could be challenging. For instance, a robotic system intended to choose apples has various challenges. In challenging circumstances, such as the presence of dust, changing light intensity and motion caused by the wind, optical systems must locate and assess the apple's ripeness. Nevertheless, gathering fruits and vegetables still calls for more than only highly developed vision technologies. A robotic arm must travel through environments with a similar number of risks in order to deftly grasp and arrange a fruit or vegetable. Thus, it can be said that the agro robotic arm must be precise enough to choose the crops without harming them and flexible enough to adapt to changing environmental conditions (Muchiri, Kimathi, 2022).

Fig. 3. Autonomous planting robot in use (Germany and Japan)

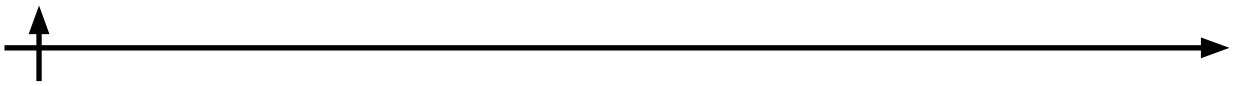
To provide an example of current work, a robotic system for harvesting sweet peppers was created as part of the EU projects Crops and follow-up SWEEPER. The primary goal of SWEEPER is to commercialize the first generation of greenhouse harvesting robots. By automating the harvest, SWEEPER optimizes the farming system. Crop models will be employed to pinpoint the peppers' general location in order to enhance the robot's cognitive capabilities. Fruit identification will be enhanced and sped up by this "model-based vision." Only the gripper will be equipped with sensors, in line with the lessons learned from the CROPS project (Arad, 2020). Hence one can concur with the notation that robotization of labor is pivotal in the field of greenhouse horticulture. The number of workers willing to complete monotonous duties in adverse rainfall conditions is steadily abating. In addition, the automation of these repetitive jobs opens up a wide range of cutting-edge technological advancements.

Another example is the Siberian Tiger, a new Russian agricultural robot from Agrirobot that could enter the market as early as 2024 and is scheduled to start field trials in 2021. A separate team of Russian scientists created the 172x172 centimeter robot to control plant disease. Using a collection of cameras and sensors, Siberian Tiger is built to traverse around fields while keeping an eye on the crops and soil. A neural network receives the gathered data and processes it for further analysis (Uskova, 2021).

Online farmer marketplaces in Uganda and India

For case, Ugandan growers vend their products at the Agro Market only during request days at specific times and locales. Due to the necessity of conserving goods, transport it to requests, and engage mediators to do so, growers face advanced costs during request days. On a market day, a farmer might not be suitable to vend all of his yield (Building a digital marketplace for agriculture in Uganda, 2024). A mobile app that eliminates mediators and factual requests by connecting buyers and merchandisers directly could affect how profitable husbandry is for growers. This Application called Agromarket day was made in Uganda by students at Makerere University. The farmer uploads images of his yield to the app along with its price, position, and phone number. A buyer browses the application's product rosters, and if he decides he wants to buy a certain item, he phones the dealer to set up the deal (Devi, Venugopal, 2022).

The Napanta App was created in India. The establishment, which is backed and fostered by AIP- ICRISAT and IIIT- Hyderabad, enables growers to incontinently pierce any type of agrarian information they bear. This digital platform was made to help agriculturists in stream-



lining their agrarian operations, boosting profitability, and getting better results. The agriculturists only need a straightforward mobile internet connection. Additionally, NaPanta provides agriculturists with comprehensive information on the vacuity, makeup, and operation styles of fungicides and germicides as well as aids in the organized tracking of their charges. Moreover, it provides connections for agro-dealers in the two states as well as a five- day rainfall forecast, details on crop insurance, and the locales of soil laboratories and cold storehouse facilities. The operation also contains offline functionality with data regarding crop and pest operation strategies for further than 100 crops for agriculturists who find it delicate to always have an internet connection (Naredla, 2018).

ET Agricultural Brain used for asset management by farmers in China

Alibaba Cloud, the Alibaba Group's cloud computing division, was founded in 2009 and is currently ranked as one of the top three IaaS providers globally and the largest provider of public cloud services in China by IDC. Alibaba Cloud offers a full range of cloud computing services to companies around the world, including start-ups, corporations, and governmental agencies, as well as merchants conducting business on marketplaces operated by the Alibaba Group (The Alibaba Cloud Intelligence Brain, 2024). The International Olympic Committee's official cloud services partner is Alibaba Cloud. Human farmers are a source of inefficiency in an optimized world. They make decisions differently because they are human and are susceptible to informational and temporal limitations. So, the reasoning goes, why not swap them out with AI models that have unlimited access to data and computing time?

The answers offered by Alibaba Cloud are designed to help agriculturists manage their resources and cover their crops more effectively. Under the term ET Agricultural Brain, they combine a number of AI approaches, speech and image recognition, climate vaticination models, and satellite data collection. Alibaba Cloud, the data intelligence arm of the Alibaba Group, asserted that the revolution of China's agricultural business was significantly told by its agricultural technology results, Agricultural Brain. ET Agricultural Brain helps agriculturists increase farmstead produce, manage healthier animals, and save labor costs to maximize return on investment. The foundation for all of this is its cloud computing structure (Bagnall, 2021).

To add on, animal products and natural resources of advanced quality have long been in demand in China. In response, ET Agricultural Brain has been working to change the agrarian industry. The system incorporates multitudinous AI algorithms, including image identification, speech recognition, and real- time monitoring of environmental data, to insure the healthy development of animals in a well- maintained environment. Thanks to the data processing and machine learning algorithm model training done by ET Agricultural Brain, livestock producers may remotely and in real time cover their farms and animals. ET Agricultural Brain can also induce high- quality milk at cheap operating costs, exclude feed waste by conforming feeds, and keep an eye on livestock conditions using image and sound recognition technologies. Several detectors are put in place to ameliorate the terrain for herd growth and to reduce human error in the breeding process (Plaksin, Trifanov, 2018).

Along with Tequ Group, other early adopters of ET Agricultural Brain include the top agricultural establishment Haisheng Group, which oversees 55 vineyards with a combined area of further than 4000 hectares, and Guoqiang Modern Farming, a rural collaborative with a base in Shaanxi that focuses on producing decoration melons (At the Shanghai Computing Conference, Alibaba Cloud launches ET Agricultural Brain, 2024). The AI program has enhanced fruit and vegetable growing for these two agriculturists. About 10,000 acres of apple trees in Haisheng have their development parameters automatically gathered by the ET Agricultural Brain, saving the farm an estimated RMB 20 million in operating costs annually.

GIS, or geographic information systems

The development of a system known as a geographic information system (GIS) was made specifically for the purpose of gathering, storing, deploying, processing, and displaying geographic data. This practice has proven to be effective in the agriculture sector in a number of ways. To make it simpler to study the soil, digital maps of the land are made and material geodetic data, such as topography and contours, are combined with other statistical data. GIS is used to determine what and where to plant using historical data and sampling (King, 2017). Thus, it should be noted that utilizing agriculture GIS tools, you may determine the vegetation levels in your field or any of its regions. Based on this knowledge, agricultural machinery can then be used to alter the quantum of seeds, nutrients, herbicides, and fertilizer for each plot. Furthermore, more intricate spatial analyses for agriculture may compare elements like soil type, wind direction, rainfall summations, slope, aspect, topography, or elevation to help with crop oversight, site suitability, drainage planning, and threat reduction from disease, flood tide, drought, and erosion. GIS can thus help an agriculturist in conforming to these various variables, tracking the health of specific crops, estimating yields from a specific field, and maximizing crop production (Ren, 2020).

IoT, or the Internet of Things

The different devices used in the field to monitor and assess the work done are connected by the Internet of effects. Cellphones have access to all data, including information on irrigation pumps, water meters, weather stations, and soil moisture levels. Sensors have been employed in agricultural activities for a while now. But the problem with the traditional approach of using detector technology was that we could not get the real- time data from the sensors (Kootstra, 2021). The sensors preliminarily stored the information in their internal memory, from which we could latterly prize it. The advent of industrial IoT has led to the usage of much more advanced sensors in agriculture. The devices with sensors are presently connected to the cloud through a cellular or satellite network (Tzounis, 2017). We may use it to get sensor data instantly and make wise decisions. From bitsy to large farms, the internet of things facilitates quick planning and decision making (Zhao, 2010).

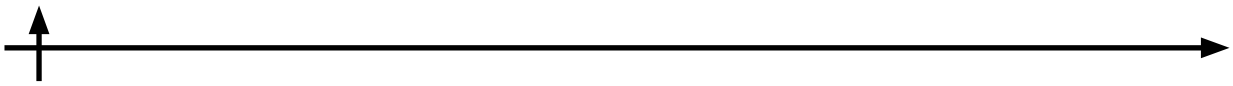
Factors that have an impact on how farming technology is used

Expensive machinery and High upkeep costs

One of the negatives of farm technology is the high upkeep costs. The high upkeep expenses of the equipment present a problem for agriculturists and small businesses. Ultramodern technological machines and gadgets are expensive to maintain that's why agriculturists are unable to keep up with them. The vast majority of agriculturists in Africa live in rural areas, where they warrant the means to maintain this premium machinery. Because they cannot afford the high upkeep expenses of new specialized equipment, farmers struggle to stay current with technology. For farmers, and extension workers to effectively communicate and share information in a cost-effective manner, the adoption of these cutting-edge technologies needs to be encouraged (Bhusal, Sagar, Khatri, 2021). However, the high cost of ICT serves as a deterrent for using ICT services. The impoverished farmers cannot afford such gadgets because android cell phones are more useful for gaining access to ICT services. For instance, in Tanzania and Nepal, the cost of adopting ICTs by farmers in the agricultural sector was the biggest obstacle to adoption. Poor and disadvantaged farmers in these two countries lack access to high-quality information on agricultural production.

Lack of Education among Agriculturalists

Since most agriculturists warrant knowledge, it might be delicate for them to understand how to use ultramodern farming technologies. Due to their traditional farming practices and limited understanding of the advantages and downsides of agricultural technology, these agriculturists



find it delicate to use it. Not everyone can profit from ultramodern agricultural technology, which is another one of its failings. Most agriculturists are unfit to duly operate ultramodern technological tools and machinery. Rural residents are prevented from using ICT due to a lack of education and understanding. Utilizing various ICT resources and getting exposed to them aid in developing a good attitude about their effects. People who utilize it frequently become aware of its advantages and adopt a positive outlook. Higher educated people have access to cutting-edge technology that allows them to study more effectively and quickly while also understanding its significance. When using ICT, a person with a greater degree of education perceives more information than a person with a lower level of education (Bhusal, Sagar, Khatri, 2021).

Health-related implications

Multitudinous research has shown that using pesticides and fertilizers exorbitantly has a dangerous impact on health. Overuse of pesticides has the drawback of eradicating salutary soil organisms that support plant growth. The topsoil could also come contaminated, away from that. Nothing additional will grow for the time being. Both pesticides and fertilizers are known to be dangerous to human health; indeed, a small quantum of skin contact with some of them can result in excruciating agony. Also, it has the potential to pollute near rivers and soils, as has been seen in Brazilian rivers. Even though the water seems harmless, it's actually veritably dangerous (Machado, 2016).

Deterioration of the environment

The majority of technical tools and innovations degrade our environment, which is veritably dangerous to people. Overuse of tractors, trucks, and other large machinery results in the release of carbon dioxide and dangerous chemical pollutants into the atmosphere. As a result, our environment has become toxic and dangerous for both humans and other living creatures. As a result, certain countries in Europe, including the UK, have developed rules regarding the use of heavy machinery on farms. Consequently, there is a major reduction in soil fertility as a result of this. The excessive use of technology in the fields reduces soil fertility. One of the most disastrous outcomes of agricultural technology is the loss of soil fertility. The soil in the fields is damaged and loses fertility due to the inordinate use of technology. Both Brazilian and American agribusiness are dealing with this. Although chemicals and fertilizers can boost productivity, they also have the eventuality to deplete soil fertility. Therefore, one can contend while a chemical or toxin might boost agrarian productivity, it can also sluggishly erode the soil's fertility, hence the overuse of agrarian chemicals like pesticides and fertilizers can harm the soil (Da Silveira, Lermen, Amaral, 2021; Imangali, Bekturganova, 2024).

Unemployment

As technology in agriculture is encouraged in the agricultural sector, agriculturists ' incomes are anticipated to increase. Robotization in agriculture will suddenly enhance farmers' income while lowering their expenditures. The output will increase coincidently with a drop in employment due to agriculture automation. As a result of the adoption of various technical advancements in agriculture, workers' services are being substituted by machines. Some of these technologies drastically dwindle the need for human workers, which is bad for society because it leads to the growth of unemployment (Da Silveira, Lermen, Amaral, 2021).

Conclusion

Due to the world population's exponential rise, the loss of agricultural land, and the shrinkage of limited natural resources, there's a critical need to increase farm yields. Our lives are impacted by technology, which is altering every element of contemporary life, including agriculture. The application of new technology developments in farming is extremely beneficent to

farmers. Developing farming technology is a pivotal approach for elevating agricultural product, establishing food sufficiency, and reducing poverty and food instability especially among smallholder farmers in sub-Saharan Africa. The high- tech equipment presently being employed in agriculture ensures that the food we consume today gets to us more snappily. Additionally, it's further nutritional, fresher, and more affordable. The food sector is witnessing a metamorphosis thanks to agricultural technology, which will only advance in the coming years. Agriculturists can work more successfully and efficiently thanks to it. There are many technological tools and devices used in agriculture. It saves a great deal of time and effort for farmers in agriculture. Thanks to ultramodern technology, agriculturists can complete a lot of work in a short period of time. Ultramodern technology results to centuries-old challenges have been applied to agriculture with the backing of IoT. This has made it easier to reconcile product, quality, and yield. Rapid action and minimized damage to the crops are assured by data collected by obtaining and integrating information from multitudinous devices for immediate use or keeping in a database for after use. On the other hand, we must recognize that technology has some adverse effects. Before using technology, we need to be apprehensive of how much damage it causes. Agriculturists must acclimatize to these changes while contemporaneously reducing the greenhouse gas emissions caused by agriculture by enforcing climate-smart techniques. The downsides of technology must be conceded, nevertheless. We must consider how much detriment technology does before employing it.

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